The power circuit of the DVR has four main parts; voltage source inverter (VSI), voltage injection transformer, DC energy storage device and low pass filter as shown in Fig.1

2.1. Injection Transformer

Its basic function is to step up the ac low voltage supplied by the VSI to the required voltage. Injection transformers used in the DVR plays a crucial role in ensuring the maximum reliability and effectiveness of the restoration scheme. It is connected in series with the distribution feeder.

2.2. Passive Filters

Passive Filters are placed at the high voltage side of the DVR to filter the harmonics. By placing the filter at the inverter side, the higher order harmonics are prevented from penetrating into transformer, thereby it reduce the voltage stress on the injection transformer. When the filter is placed on the high voltage side, since harmonics can penetrate into the high voltage side of the transformer, a higher rating transformer is required.

2.3. Voltage Source Inverter

Voltage Source Inverter converts the dc voltage from the energy storage unit to a controllable three phase ac voltage. The inverter switches are normally fired using a sinusoidal Pulse Width Modulation scheme.

2.4. Energy Storage Device/Control System

It provides the real power requirement of the DVR during compensation. Lead-acid Batteries, Flywheels, Super conducting Magnetic Storage (SMES) and Super capacitors can be used the storage device. The capacity of energy storage device has a big impact on the compensation capability of the system. Compensation of real power is essential when large voltage sag occurs.

3. Space Vector Pulse Width Modulation

Space vector pulse width modulation technique is an advanced, computation–intensive PWM method and is possibly the best among all the PWM techniques for variable-frequency drive applications. The circuit model of a typical three-phase voltage source PWM inverter is shown in figure 2. S1 to S6 are the six power switches that shape the output, which are controlled by the switching variables a, a′, b, b′, c and c′. When an upper transistor is switched on, i.e., when a, b or c is 1, the corresponding lower transistor is switched off, i.e., the corresponding a′, b′ or c′ is 0. Therefore, the on and off states of the upper transistors S1, S3 and S5 can be used to determine the output voltage.

The objective of space vector PWM technique is to approximate the reference voltage vector Vref using the eight switching patterns. One simple method of approximation is to generate the average output of the inverter in a small period, T to be the same as that of Vref in the same period.

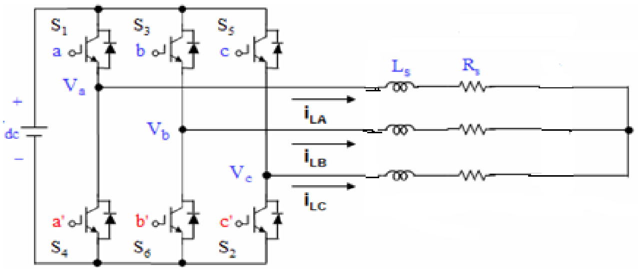

Figure 2: Phase Voltage Source PWM Inverter.

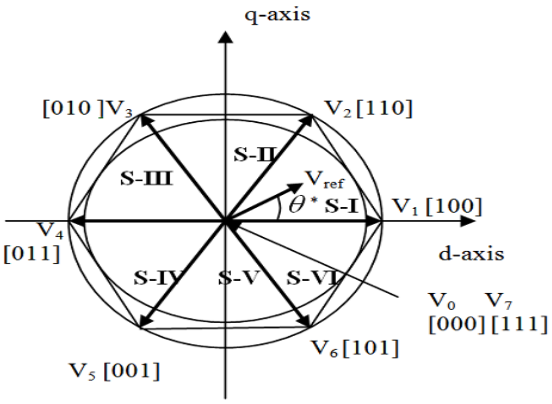

Figure 3: Vector Representations of the Switching Gates.

3.1 Determination *of V_d, V_q, V_{ref}, And Angle (α)*

From fig 3 The V_d, V_q, V_{ref}, and angle (α) can be determined as follows:

$$Vd = Van - \tfrac{1}{2}Vbn - \tfrac{1}{2}Vcn \ (1)$$

$$Vq = Van + \frac{\sqrt{3}}{2}Vbn - \frac{\sqrt{3}}{2}Vcn \ (2)$$

$$\alpha = \tan^{-1}(Vd/Vq) \ (3)$$

$$|V| = \sqrt{(Vd^2 + Vq^2)} \ (4)$$

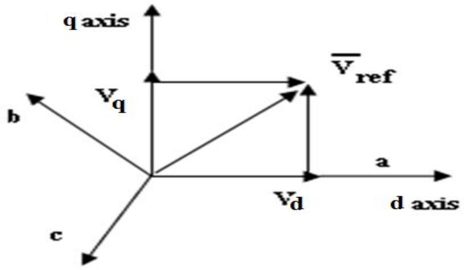

Figure 4: Voltage Space Vector and its Components in (α, β).

3.2 Determination of Time durations T_1 T_2 T_0

From fig 3, The switching time duration can be calculated as

$$T_1 = \frac{\sqrt{3}}{V_{dc}} T_z \left|V_{ref}\right| \left(\sin\frac{n\pi}{3}\cos\theta - \cos\frac{n\pi}{3}\sin\theta\right) \ (5)$$

$$T_2 = \frac{\sqrt{3}}{V_{dc}} T_z \left|V_{ref}\right| \left(\sin\theta\cos\frac{(n-1)\pi}{3} - \cos\theta\sin\frac{(n-1)\pi}{3}\right) \ (6)$$

$$T_0 = T_z - (T_1 + T_2) \ (7)$$

$$T_z = \frac{1}{f_z}$$

Where n=1 through 6, i.e. sector 1 to 6 and $0 \le \theta \le 60^0$

4. Simulation Analysis

To obtain the above simulated results, inverter was simulated using SIMULINK matlab7.9. Parameters used for simulation are as follows: fm=50 Hz, load is assumed to R-L load where R=40 ohms, L=172 Henry. The power quality issues i.e. voltage sag and swell compensated by using dynamic voltage restorer.

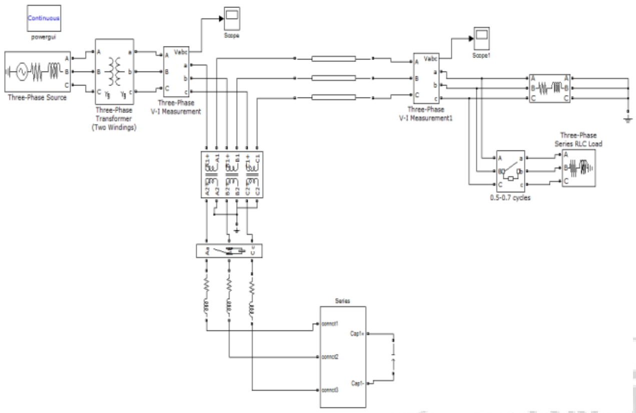

Figure 5: Simulink Block Diagram of Closed Loop System when sag was occurs.

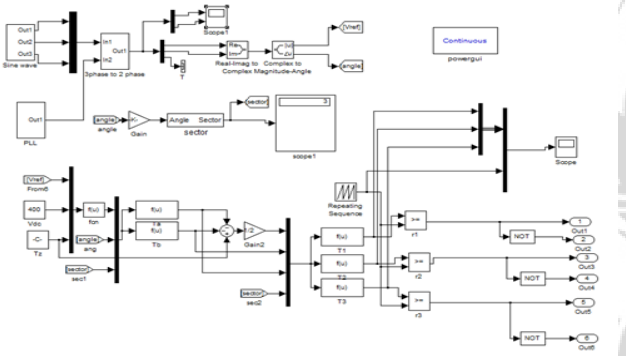

Figure 6: Simulink block diagram for space vector pulse width modulation.

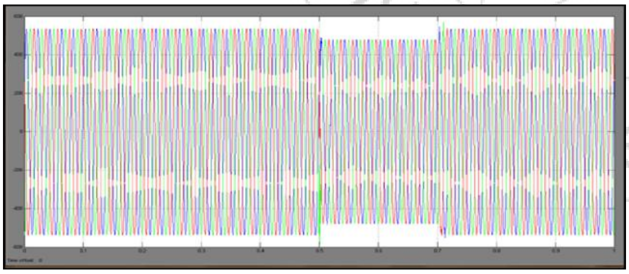

Figure 7: Source Side Voltage before Compensation When Sag Was Occurs

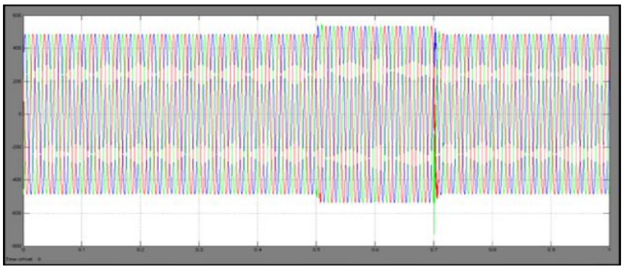

Figure 8: Source Side Voltage before Compensation When Swell Was Occurs.

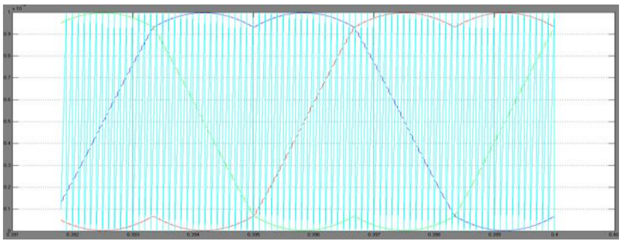

Figure 9: Output of Generated switching pulses for the Inverter.

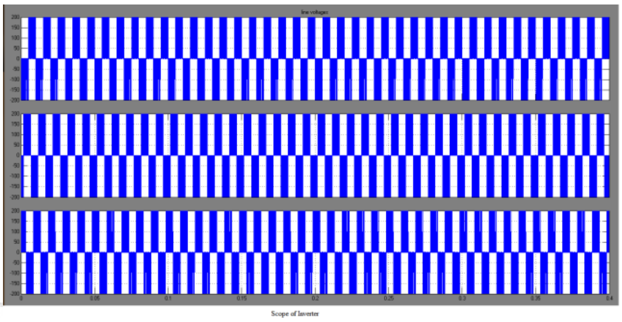

Figure 10: Output three phase Inverter

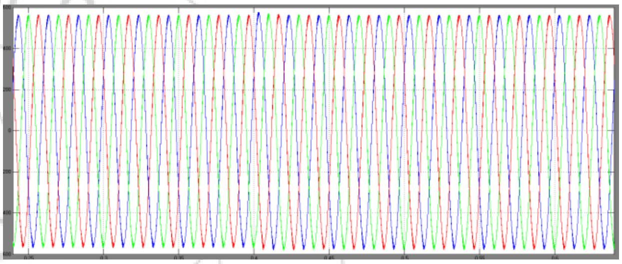

Figure 11: Source Side Voltage after Compensation When Sag Was Occurred.

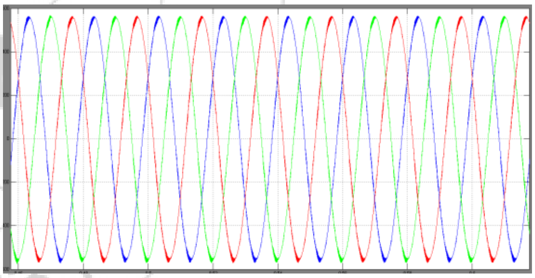

Figure 12: Source Side Voltage after Compensation When Swell Was Occurred.

5. Conclusion

This paper presents the Dynamic Voltage Restorer as an effective custom power device to mitigate the Voltage Sag and Swell. The highly developed graphic facilities of MATLAB have been used to conduct all aspects of model implementation. The mitigation Capability of DVR depends on the maximum load and limited by the energy storage capacity.

The Simulation results clearly show the performance of DVR in mitigating Voltage Sag and Swell. From result it is also observed that for increasing load demand the DC energy storage capacity also increases. The DVR handles both balanced and unbalanced situations without any difficulties and injects the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value.

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